

# Verification and Regionalization of Trauma Systems

## The Impact of These Efforts on Trauma Care in the United States

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### KEYWORDS

• Trauma systems • Verification • Regionalization

### KEY POINTS

- A trauma system is a coordinated and organized approach to the delivery of care to injured patients within a community implemented to enhance community health and to ensure the effective use of resources.
- Efforts to develop trauma systems in the United States have resulted in the implementation of a system of care for the seriously injured in most states and within the US military, particularly in relation to recent major conflicts in the Middle East and Southwest Asia.
- The methodology intended to verify trauma systems is focused on performance based on patient-centered outcomes.
- Trauma systems are effectively regionalized to the extent that the most seriously injured patients in a community are cared for at designated tertiary care trauma centers.
- Outcome measures, beyond hospital-based mortality, such as risk-adjusted rates of preventable morbidity and quality-of-life indicators, may serve as a future means to verify trauma systems.

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## INTRODUCTION AND BACKGROUND

A trauma system is an organized approach to the delivery of care to injured patients within a community. Trauma systems operate within defined geographic boundaries and serve to provide multidisciplinary care to injured patients. Through statewide coordination, trauma systems serve to not only enhance community health but to also ensure efficient use of medical resources.

In 1966, the National Academy of Sciences published their landmark article, "Accidental Death and Disability: The Neglected Disease of Modern Society,"<sup>1</sup> bringing to light the need for an organized approach to the treatment of injured patients. With the publication of the American College of Surgeons Committee on Trauma guideline "Optimal Hospital Resources for the Care of the Seriously Injured"<sup>2</sup> a decade later, the framework for what would become the modern trauma system was established.

In 2007, Hoyt and Coimbra<sup>3</sup> published a comprehensive article detailing the history, organization, and future directions of trauma systems within the United States. This article serves to provide an update of the developments that have occurred in trauma systems in the areas of system verification and regionalization in the intervening years since the original publication.

## STATES WITH TRAUMA SYSTEMS

As indicated, trauma systems, as opposed to trauma centers, represent a coordinated and organized approach to the care of the injured in a region versus a medical treatment facility. It is important to recognize that regions of trauma care may cross state and even international boundaries (as is the case of the US Military Joint Trauma System). Although the term region is geography-centric and defined by boundaries, the term system is patient-centric and defined by a coordinated and organized approach to trauma care. At the time of publication of the original article, approximately 50% of states had statewide trauma systems,<sup>3</sup> which increased to 90% as of October 2011.<sup>4</sup>

## US MILITARY TRAUMA SYSTEMS

The development of the civilian trauma system has been closely tied to lessons learned by America's military during armed conflict through the last 2 centuries. Although it contributed early to the formation of the civilian trauma system, in the absence of armed conflict, the United States military trauma system stagnated in the 1980s and found itself unprepared for the delivery of trauma care in the deployed environment during Operations Desert Shield and Desert Storm.<sup>5</sup> In response to the terrorist attacks of September 11, 2001, Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) were initiated. An effort to develop a military trauma system modeled after the civilian system while accounting for the unique situations encountered in the battlefield environment was initiated in May 2004. In November 2004, the Joint Theater Trauma System (JTTS) was implemented as a result of these efforts. **Table 1** differentiates some of the conventional and symmetric definitions of the agents, ways, means, and ends of violence and its intended or unintended consequence in a region or population. Terrorist activity may exploit conventional definitions and understandings of the agents, ways, means, and ends of violence in a population; as such, its domain is asymmetrical and overlaps the military and civilian community.

To allow for ongoing performance improvement and research, the Joint Theater Trauma Registry (JTTR) was developed. This comprehensive database includes injury

**Table 1**  
Conventional definitions of the agents, ways, means, and ends of violence on the battlefield and civilian community

	Battlefield	Civilian Community
Agents	Military combatants	Criminals, constabulary responders
Ways	Military operations	Criminal activity and law enforcement
Means	High energy weapons and explosives	Low energy weapons, motor vehicle crashes, falls, natural disasters
Ends	Military objectives	Illegal purposes, maintenance of civil order

and outcome data entered into a central database from a concise form (Fig. 1). In 2 recent reviews by Eastridge and colleagues,<sup>6,7</sup> the positive impact that the JTTS has had on the care delivered to the injured soldier, airman, sailor, and marine is evident. In a review of 3 of the 27 evidence-based clinical practice guidelines (CPGs) implemented after the formation of the JTTS,<sup>6</sup> clinically and statistically significant improvements were seen in the following areas:

- Burn resuscitation-associated abdominal compartment syndrome mortality
- Hypothermia on presentation
- Massive transfusion mortality (damage control resuscitation).

To further highlight the effectiveness of the JTTS, this article demonstrates a 5.2% mortality rate after battlefield hospital admission, which is comparable to an age-matched cohort case fatality rate of 4.3% from the National Trauma Data Bank. In their more recent review of the JTTS, Eastridge and colleagues<sup>7</sup> show the significant impact that this trauma system has had in the care of the wounded service member, demonstrating a 54% decrease in aggregate postinjury complications after the development and implementation of the aforementioned 27 evidence-based CPGs. The implemented CPGs are available at <http://www.usaisr.amedd.army.mil/cpgs.html>.

In 2010, the joint trauma system (JTS) concept was introduced in the Department of Defense (DoD). The newly described JTS organization would serve as a consulting agency to each of the regional or theater US military combatant commands as a resource for deploying a JTTS if conflict- or disaster-related contingencies required an organized oversight of trauma care.<sup>8</sup> This organization has been formally recognized and funded in the DoD for the next 5 years, and a tactical plan to operationalize its funding resources is in development.

Funding that continues beyond the duration of the current conflict in the US Central Command Area of Responsibility supports the primary goal of the JTS: to serve as an enduring resource for DoD trauma care and trauma systems, regardless of region, command, or contingency. To maintain that capability and relevance in trauma care and systems, the JTS is positioned to be sustained as a surgeon lead joint military service entity that remains agile and current with advances in injury care.

To ensure its perpetual relevance and excellence in DoD trauma care, the JTS has strengthened its relationship with the American College of Surgeons Committee on Trauma (ACS COT) and aligned its activities with COT trauma systems by seeking appointment of its trauma surgeon leadership to COT military region leadership positions and development of a US military manual entitled: *Joint Trauma System: Development, Conceptual Framework, and Optimal Elements*. This document is


PHYSICIAN TRAUMA TREATMENT RECORD (FORWARD RESUSCITATIVE CARE) (Last 28)											
(All shaded areas mandatory for Joint Theater Trauma Registry data collection)											
DATE: _____					VITAL SIGNS						
TIME OF INJURY: _____					T _____ P _____ R _____ BP _____ / _____ O2 Sat _____						
TIME OF ARRIVAL: _____					LOCATION OF PRE-HOSP. CARE: _____						
HISTORY & PHYSICAL					MECHANISM OF INJURY						
INJURY DESCRIPTION (AB) laceration (AMP) laceration (AV) laceration (BL) bleeding (Bum) %TBSA _____ (C) crepitus (D) deformity (DO) degloving (E) ecchymosis (FX) fracture (F) foreign body (GSW) Gun Shot Wound (H) hematoma (LAC) laceration (PW) Puncture Wound (P) pain					PAIN Present: _____ Se Strong Wk Weak D= Doppler A= Absent						
					MECHANISM OF INJURY <input type="checkbox"/> Assault/Fight <input type="checkbox"/> Blast/Explosion <input type="checkbox"/> Blunt Trauma <input type="checkbox"/> Bomb <input type="checkbox"/> Building Collapse <input type="checkbox"/> Burn <input type="checkbox"/> Chemical <input type="checkbox"/> Crush <input type="checkbox"/> Drowning <input type="checkbox"/> Fall <input type="checkbox"/> Flying Debris <input type="checkbox"/> Grenade <input type="checkbox"/> GSW/Bullet <input type="checkbox"/> Helo Crash <input type="checkbox"/> Hot Obj/Liquid <input type="checkbox"/> IED <input type="checkbox"/> Knife/Edge <input type="checkbox"/> Landmine <input type="checkbox"/> Machinery <input type="checkbox"/> Mortar <input type="checkbox"/> Multi-Bag <input type="checkbox"/> MVC <input type="checkbox"/> Plane Crash <input type="checkbox"/> Rad/Nuclear <input type="checkbox"/> Single Frag <input type="checkbox"/> UXO <input type="checkbox"/> Other _____						
HISTORY AND PRESENTING ILLNESS: _____					CARE DONE PRIOR TO ARRIVAL						
Airway: <input type="checkbox"/> no <input type="checkbox"/> yes Type: _____ IVs: <input type="checkbox"/> no <input type="checkbox"/> yes Type: _____ Amt: _____ Chest tube: <input type="checkbox"/> no <input type="checkbox"/> yes R L (circle as applicable) Temp control measure: <input type="checkbox"/> no <input type="checkbox"/> yes Type: <input type="checkbox"/> Body Bag <input type="checkbox"/> Other Intravenous access: <input type="checkbox"/> no <input type="checkbox"/> yes Location: _____ Tourniquet: <input type="checkbox"/> None Type: _____ Time On: _____ Time Off: _____											
HISTORY & PHYSICAL					INITIAL PROCEDURES / DIAGNOSTICS						
Head & Neck: _____ Tympanic Membranes: _____ Clear R <input type="checkbox"/> L <input type="checkbox"/> Blood R <input type="checkbox"/> L <input type="checkbox"/>					<input type="checkbox"/> C-collar <input type="checkbox"/> Intubate <input type="checkbox"/> Airway (oral/nasal) <input type="checkbox"/> CRP <input type="checkbox"/> Chest Tube <input type="checkbox"/> R L Output: _____ Blood nls: _____ Air <input type="checkbox"/> Needle Decompression <input type="checkbox"/> R L Output: _____ Blood nls: _____ Air						
Chest: _____					<input type="checkbox"/> Pericardocentesis <input type="checkbox"/> Thoracotomy <input type="checkbox"/> FAST <input type="checkbox"/> DPL <input type="checkbox"/> WGOG <input type="checkbox"/> Pelvic Binder <input type="checkbox"/> Foley						
Abdomen: _____					<input type="checkbox"/> Closed Reduction <input type="checkbox"/> EXT Flotation <input type="checkbox"/> Splint <input type="checkbox"/> Wound Washout <input type="checkbox"/> Tourniquet Type: CAT / SOFT / Other Time On: _____ Time Off: _____						
Pelvis: <input type="checkbox"/> Stable <input type="checkbox"/> Unstable					<input type="checkbox"/> Closed reduction <input type="checkbox"/> EXT Flotation <input type="checkbox"/> Splint <input type="checkbox"/> Wound Washout <input type="checkbox"/> Tourniquet Type: CAT / SOFT / Other Time On: _____ Time Off: _____						
Upper Extremities: _____					<input type="checkbox"/> Closed Reduction <input type="checkbox"/> EXT Flotation <input type="checkbox"/> Splint <input type="checkbox"/> Wound Washout <input type="checkbox"/> Tourniquet Type: CAT / SOFT / Other Time On: _____ Time Off: _____						
Lower Extremities: _____					<input type="checkbox"/> Closed Reduction <input type="checkbox"/> EXT Flotation <input type="checkbox"/> Splint <input type="checkbox"/> Wound Washout <input type="checkbox"/> Tourniquet Type: CAT / SOFT / Other Time On: _____ Time Off: _____						
Neuro: GCS: _____ E _____ M _____ V _____ Motor Deficit: _____ R UE/L L UE/L C-Spine Tender: Yes <input type="checkbox"/> No <input type="checkbox"/>					<input type="checkbox"/> Seized <input type="checkbox"/> Chemically Paralyzed <input type="checkbox"/> Seizure Protocol <input type="checkbox"/> Mannitol <input type="checkbox"/> Intracranial <input type="checkbox"/> Central Line <input type="checkbox"/> A-Line						
Skin: Burn: 1st 2nd 3rd %TBSA Size mm mm					<input type="checkbox"/> Begin Temp _____ Time/Date _____ <input type="checkbox"/> End Temp _____ Time/Date _____ Temperature Control Procedure: <input type="checkbox"/> Bar Huggers <input type="checkbox"/> Chilled Blanket <input type="checkbox"/> Cooling Blanket <input type="checkbox"/> Int Resp Fluid Warmer <input type="checkbox"/> Body Bag <input type="checkbox"/> Other _____						
CBC		CHEMISTRY		LFTs		URINALYSIS		ALLERGIES			
Amylase: _____ Alk Phos: _____ LDH: _____ BUN: _____ SCOT: _____ SCPT: _____ Other: _____		SpO2: _____ pH: _____ Chem: _____ WBC: _____ RBC: _____ WBC: _____ Sact: _____ HCO3: _____		SpO2: _____ pH: _____ Chem: _____ WBC: _____ RBC: _____ WBC: _____ Sact: _____ HCO3: _____		<input type="checkbox"/> NKDA <input type="checkbox"/> ASA <input type="checkbox"/> PCN <input type="checkbox"/> Sulfis <input type="checkbox"/> Morphine <input type="checkbox"/> Codeine <input type="checkbox"/> Latex <input type="checkbox"/> Other _____					
PT/INR/PTT		ABO		MEDICATIONS		IV FLUIDS/BLOOD PRODUCTS		PMH			
PT: _____ INR: _____ PTT: _____		FIO2: _____ pH: _____ pCO2: _____ pO2: _____ Sat: _____ BE: _____		VENT: YES NO ETT Size: _____		<input type="checkbox"/> DT <input type="checkbox"/> Abx <input type="checkbox"/> Versed <input type="checkbox"/> Morphine <input type="checkbox"/> Fentanyl <input type="checkbox"/> Other: _____		<input type="checkbox"/> Crystalloids cc's NS LR <input type="checkbox"/> Colloids cc's <input type="checkbox"/> PRBC's units <input type="checkbox"/> FFP units <input type="checkbox"/> Whole Bld units <input type="checkbox"/> Cryo units <input type="checkbox"/> PLTs units		<input type="checkbox"/> Unknown <input type="checkbox"/> HTN <input type="checkbox"/> None <input type="checkbox"/> DM <input type="checkbox"/> Cardiac <input type="checkbox"/> Ulcer <input type="checkbox"/> Respiratory <input type="checkbox"/> Other	
Patient NAME/ID: _____ First MI MTF transferred from: _____ Date: (dd,mm,yy) Last: _____ First MI MTF transferred from: _____ Date: (dd,mm,yy) SSN/ID: _____ DOB (ddmmyy) Age: _____ MTF: _____ ASD/NAI September 2005 This Form is Subject to the Privacy Act of 1974 Page 1 of 2											

Fig. 1. JTTR record.

intended to serve as the ACS COT regional trauma systems manual. It is to be a perpetual and regularly updated resource for US military trauma systems definition. These efforts mirror the important relationship that has developed between US military and civilian trauma care providers and systems in the decade preceding and since the September 11th attacks.<sup>8</sup>

In addition to the publication of a trauma systems manual, the development of a theater operations manual to describe the structure, function, and tactical deployment of a trauma system to future contingencies, regions, and commands has been recently recommended to the Defense Health Board. This recommendation is now under review for implementation at JTS. This manual is intended to capture all

currently available stand-up and operational procedures for all elements of the theater trauma system and accelerate the speed and efficacy of future JTTS.<sup>9</sup>

## LEGISLATIVE ACTIVITY AND AUTHORIZATION

### *Funding*

To plan, implement, and evaluate statewide or regional trauma systems, sufficient funding is required. All components of the trauma system require funding, including the following<sup>10</sup>:

- Prehospital care
- Acute-care medical facilities
- Rehabilitation centers
- Prevention programs.

Of the 45 states with statewide trauma systems, only 60% of them are funded.<sup>4</sup>

In his comprehensive review of trauma system funding, Geehan<sup>11</sup> discusses many of the changes in the medical landscape of today that have affected the funding of trauma centers. It is difficult to accurately assess the cost of a functioning trauma center, although recent estimates have ranged between \$2.7 million and \$4.5 million yearly.

Given the unpredictable nature of injured-patient arrivals, trauma centers must have their facilities and staff at the ready at all times. At present, there is no effective method to bill for this readiness. The *Current Procedural Terminology* coding system does make an allowance for physician standby time, but there is a 30-minute time limit. Additionally, the code is assigned a low relative value unit of 1.2 and is not routinely reimbursed by Medicare or Medicaid.<sup>11</sup> A revenue code (68x) was approved by the American Hospital Association to charge for trauma activation. To bill for this code, patients must arrive at the trauma center by trained prehospital care providers, meaning that those patients that are brought in by privately owned vehicles or who bring themselves to the trauma center are not eligible for use of this code. Despite being available for use since 2002, a recent survey conducted to determine the usage rate of this code found that payers only variably accept it.<sup>12</sup>

Because of the difficulty in billing for readiness, a stream of sustainable funding is desirable for any trauma system. **Box 1** lists various funding methods states have used to support trauma systems.<sup>4,10</sup>

Given the frequently encountered difficulties in securing and maintaining adequate funding, it behooves the trauma center (and the trauma system) to limit costs. Methods that have been proposed to achieve this end include varying staffing throughout the day based on peak patient-volume times and minimizing staff turnover to prevent excess expenditure on recruitment and training of new personnel.

#### **Box 1**

#### **Funding mechanisms for state supported trauma systems**

Moving traffic violation fees  
 Driver's license renewal fees  
 Gambling revenue compacts  
 Cigarette taxes  
 Crime victim funds  
 911 call surcharge

## VERIFICATION OF US TRAUMA SYSTEMS AND THE IMPACT ON TRAUMA CARE

### *Valuation of US Trauma Systems*

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Public valuation and expectations of trauma systems have been consistently demonstrated.<sup>13,14</sup> This perception has almost certainly buoyed the acceptance and subsequent development of trauma systems in the United States.<sup>4</sup> Nonetheless, the same level of commitment has not applied to the willingness of electorates and government to consistently underwrite the cost of trauma systems. This factor is likely the primary factor that has generated the mismatch between public perception and expectation and the realities of the current state of US systems.<sup>13–15</sup> Three years before the 2007 Hoyt/Coimbra SCNA review<sup>3</sup> of US trauma systems, the National Foundation for Trauma Care (now known as The Trauma Center Association of America) described a crisis in trauma care because of the loss of trauma centers across the United States.<sup>16</sup> Unfortunately, the crisis has been exacerbated by recent unfavorable trends in reimbursements set against the backdrop of an evolving global financial crisis.<sup>11,17</sup> In this environment of austerity, the impact of effort that verifies the benefit and potentially the requirement of trauma systems as an imperative for public health would be difficult to understate. So, given the continued erosion and the real potential for outright collapse of US trauma systems, a body of work that seeks to evaluate the positive impact of US trauma systems on patient care continues to be accumulated and refined. Whether this can win appropriated fiscal support to sustain the US trauma system remains to be seen.

### *Verification of Trauma Systems as Opposed to Trauma Centers*

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The elements that constitute a trauma center are quantifiable in component or elemental form, but their organized application is the process that produces the favorable results that are attributed to the care of the injured in designated hospitals. Verification that a hospital has demonstrated the capability and ongoing potential to operate as a trauma center involves the evaluation of the following areas:

- Institutional commitment
- Injury volume and acuity
- Facility layout, dedicated material, and human resources
- Operation of the clinical trauma program
- Trauma performance improvement program.

Although most centers look to verification by the lead external agency for care of the injured, the ACS, some centers have opted out of that process to rely on an internal validation process. Factors that ultimately result in trauma center *designation*, a governmental action, may include review and consideration of an internal or external verification process. The relationship between formal trauma center verification and improved outcomes has been empirically reported and has been demonstrated across a spectrum of quality indicators that include in-hospital mortality, lengths of stay, lethal injury complex outcomes, and resource use.<sup>18–21</sup> These results are particularly compelling in that trauma centers care for a more seriously injured patient population with a paradoxically higher burden of predicted morbidity and mortality.<sup>18–20</sup>

Reasons that underlie this paradox are presumably based largely on the commitment of facility resources to trauma care. However, beyond the use of facility material resources, resultant improvements in patient outcome have also been attributed to the synergy that results from the commitment of facility leadership and staff. It is this commitment that is presumed to drive a shift in organizational culture that energizes and sustains a constant state of readiness focused on the care of the seriously injured

and in effect transforms a hospital into a trauma center.<sup>11,19</sup> That culture of commitment and readiness may encompass the continuum of injury care from out of the hospital to hospital and through rehabilitative phases when the continuum is organized as a trauma system. Although individual components may be functioning optimally, it does not necessarily follow that when integrated across the continuum of care, they perform at the same high level as a system.<sup>22,23</sup> As reported by Hoyt and Coimbra in 2007, the 2006 publication, "Model Trauma System Planning and Evaluation," by the US Department of Health and Human Services, Health Resources and Services Administration outlined a public health model for the evaluation of trauma systems defined by system assessment, policy development, and assurance (Fig. 2).<sup>23</sup> In this era of fiscal austerity, the continued development, evaluation, and sustainment of trauma systems within this model hinges on evidence that verifies trauma systems provide a measureable and positive impact on patient outcomes while containing costs.

### System Evaluation and Verification Efforts and Performance Measures

The evaluation of trauma center performance has relied on the assessment of quality indicators that exist in 4 principle domains as summarized in Table 2. Although a large

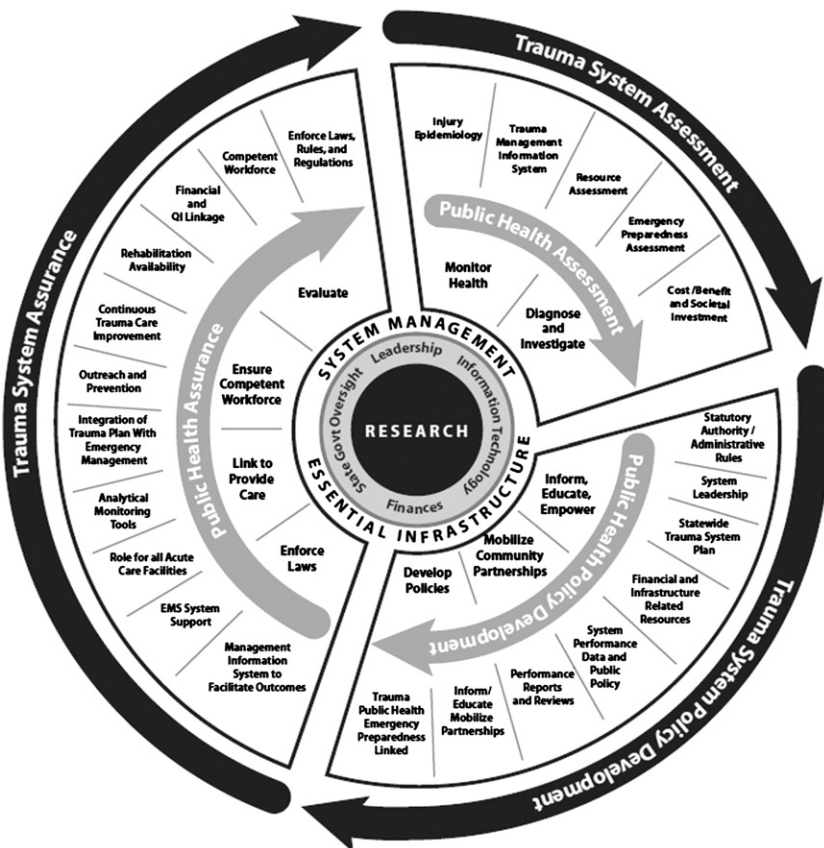


Fig. 2. The public health approach to trauma system development. (Data from United States Department of Health and Human Services Health Resources and Services Administration. Model trauma system planning and evaluation August 2006.)

Table 2 Quality indicators for trauma center performance	
Phases of care	Prehospital Hospital Posthospital Secondary prevention
Structure	Field triage Advanced imaging availability Rehabilitation referral practices Alcohol screening
Process	EMS response time ED dwell time Rehabilitation facility wait time Alcohol recidivism
Outcome	Death Admission to long term care Recurrent injury

Abbreviations: ED, emergency department; EMS, emergency medical services.

number of quality indicators arise from these domains, the reliability and validity of these indicators as surrogates for center-focused quality trauma care (ie, improved patient outcomes after program implementation) has not been firmly established, with the potential exception of peer-reviewed preventable death.<sup>24,25</sup> The reliability and validity of methodology intended to evaluate trauma system performance is faced with the same limitations; however, as with trauma center evaluation, correlation with patient-centered outcomes is the goal.<sup>26,27</sup>

**Mortality**

The evaluation of trauma system performance begins with review of preventable deaths by expert panels, pretrauma and posttrauma system implementation. The prediction of mortality in an injury population has been the subject of much investigation and, to some extent, controversy. Two primary methodologies have been applied. The Trauma and Injury Severity Score (TRISS) relies on a national injury registry that compares observed deaths with predicted deaths based on estimated probabilities of survival that are derived from the Major Trauma Outcome Study.<sup>13,28</sup> The TRISS methodology has been criticized because its database was derived from voluntary hospital participation in the 1980s, although the coefficients for this scoring system have been updated in 1995 and 2009. Nonetheless, this approach may not produce a reliable and nationally representative survival norm when applied to current trauma centers.<sup>29</sup> The alternative is the International Classification of Diseases Injury Severity Score (ICISS), which relies on a survival risk ratio calculated for each *International Classification of Diseases (ICD)* code. The ICISS has been demonstrated to have superior ability to predict survivorship<sup>30</sup> and was also shown to perform well in terms of predicting hospital lengths of stay and costs.<sup>31</sup> Although the ICISS has been shown to underperform compared with anatomic injury measures, its overall performance as a predictor of mortality and, thus, as a tool for establishing predicted and, by extension, preventable mortality has been met with acceptance.

Mortality is an appealing outcome because of the ease of classification and identification within a data set. A meta-analysis of 14 studies between 1992 and 2003 reported a 15% mortality reduction when trauma care was provided in trauma centers

in an established trauma system based on an odds ratio assessment.<sup>29</sup> Since this publication, several studies have demonstrated reductions in mortality, up to 25%, either by comparing outcomes based on facility (trauma center vs nontrauma center) or chronology (pretrauma and posttrauma system implementation).<sup>15,27,30,31</sup> The implementation of a trauma system in the OIF/OEF theaters of combat operations was demonstrated to be associated with lower mortality from burns and abdominal compartment syndrome from 36% to 18% and with massive transfusion from 32% to 20%. This finding has been attributed to the adoption of evidence-based theater clinical practice guidelines that were deployed across the system.<sup>5,6</sup> It should be noted that these results were primarily associated with the care of the combat injured in OIF where the United States played a much larger role in implementation and assurance of the JTTS versus OEF (Afghanistan) where the trauma system has a much larger component of international participants, primarily from the European continent and the United Kingdom. A case-matched comparison of trauma outcomes in these two very different systems has yet to be accomplished, but it is likely that results pertaining to mortality outcomes are comparable. This assumption is based on the observation that the implementation of trauma systems outside of North America has realized comparable improvements in injury-related mortality.<sup>32</sup>

The overall effectiveness of relying on the mortality advantage to establish the value of a trauma system has its limitations because of the low proportion of deaths within a trauma population. This point is particularly relevant in a system with a realistic potential of providing quality care and, thus, influencing favorable outcomes in the population where it is most likely to matter: the one between the populations who are likely to recover and those for whom effective care is not a reasonable possibility.<sup>33</sup> The limitation of mortality as a facile indicator is exacerbated in systems whereby patient volumes and visibility are low but relative risk of adverse outcome is high, such as the rural setting where, although small in absolute magnitude, the relative opportunity to impact care, lower risk, and improve outcomes is high.<sup>34</sup> In addition, longitudinal evaluations are unlikely to demonstrate continued dramatic reductions in mortality once the system matures.<sup>31,33</sup> So, once system maturity has been achieved, a stabilized reduction in mortality may serve to reset the bar of public expectation; early gains made in mortality rates may be lost to public memory. Although the inclusive trauma system has won preference to the exclusive system, a halo effect in the mature trauma system has also been described, which may also lead to public misperceptions because of the misattribution of trauma-center care outcomes to non-trauma hospitals.<sup>27,30,35</sup>

### ***Beyond In-Hospital Mortality***

Although mortality has been described as low-hanging fruit in the verification of trauma systems, several other indicators have been evaluated in the effort to verify the impact of trauma systems on trauma care in the United States. This body of work has primarily focused on the in-hospital phase of care. Efforts to verify the impact of trauma systems on out-of-hospital care have largely focused on the value of system-based out-of-hospital decision making by evaluating outcomes, again largely as a function of mortality, although the effect of appropriate triage has also been reported in terms of cost savings.<sup>36–38</sup> Following implementation of a rural trauma system in Iowa, investigators reported a significant reduction in the risk of death associated with traumatic brain injury.<sup>39</sup> Although the ideal approach and algorithm to guide out-of-hospital decision making remains in question, the value of an organized approach in this phase of care is not in dispute,<sup>40,41</sup> and continued efforts to verify the value of system-based trauma care in addition to efficacy of triage include emergency

medical services response time and prehospital deaths. However, the enduring hospital-centric, surgical audit-based system for data collection for the evaluation of the system complicates the process of effective capture and evaluation of prehospital data.<sup>24</sup> Although not yet linked to a direct outcome measure, the implementation of the US Military Joint Trauma System Clinical Practice guideline (JTS web site: [http://usaisr.amedd.army.mil/joint\\_trauma\\_system.html](http://usaisr.amedd.army.mil/joint_trauma_system.html)) for the prevention of hypothermia, primarily addressed to the out-of-hospital phase of care, resulted in a 7-fold reduction in the percent of patients demonstrating hypothermia on presentation.<sup>6</sup> The overarching implication of this body of work suggests that the acceptance and practice of trauma care in accordance with theater clinical practice guidelines resulted in a reduction in variance across the system (primarily in the out-of-hospital setting in this case) that was realized in improved hypothermia rates. The validation of this implication requires an assessment of out-of-hospital patient care practice. Effective capture of prehospital data in a combat theater of operations has been a difficult challenge; but early efforts have demonstrated improvement in that capability, although, to date, no means other than case-by-case expert evaluation of out of standards missions (based on response times) is the sole means of evaluating impacts on patient outcomes. As efficacy of system-based registration of out of hospital phases of care improves, system based evaluation of out of hospital care and related patient outcomes will likely continue to improve.<sup>8</sup>

The evaluation of system impact on the posthospital phase of trauma care is in its early stages but may be linked to more profound indicators of quality outcomes that relate to a potential reduction in the burden of long-term disability and years of productive life lost.<sup>27</sup> Inclusion of long-term psychological and emotional sequelae, such as injury-associated posttrauma stress disorder, although not a consistent measure of injury-related functional recovery, may be included in a more far-reaching evaluation of structural and process trauma systems outcomes.<sup>42</sup> The practical application of such investigation will rely on effective means of identifying and evaluating injury-related disability in populations. Adapting a combination of existing generic disability assessment tools may facilitate work in this area.<sup>43,44</sup>

The economic burden of trauma and its related disability is large. In a pay-for-performance culture, the practical value of demonstrating the ability of trauma systems to contain costs has been another avenue of outcomes-related investigation. In response to failure of a state trauma system to win legislative funding, Durham and colleagues<sup>15</sup> produced a report designed to address the effectiveness of trauma systems, which was questioned by the governor in vetoing the legislation. The governor stated: "Trauma centers save lives, but so do hospitals that are not designated trauma centers. What is the difference derived from adherence to our (trauma system) regulations? If state government is to initiate trauma center unique payments, we must first know we are paying for performance."<sup>15</sup> The investigation generated in response to this statement and its related mandate was designed to answer 3 key questions: (1) Does treatment at a trauma center versus a nontrauma center improve survival? (2) Is the system cost effective? (3) Is access to the system equitable?

The investigation showed a mortality reduction of 18% in trauma patients cared for in designated trauma centers, which is comparable with the survival advantage that has been attributed to trauma systems. Although the absolute cost for care at a trauma center was higher than a nontrauma center by \$21,875 in charges, the marginal cost per life saved ranged from \$32,514 to \$122,750, which translated to \$746 to \$2815 per life-year saved; a savings that is in parity with other major public health programs. Access was found to be superior to the national average but could be improved by the addition of trauma centers in underserved areas. The investigators also reported

an oversaturation of one region of the state with level II trauma centers, limiting volumes (from 202 to 368 patients), which the investigators attributed to political reasons, indicating that 1 of the 8 key criteria for trauma system development (authority to designate, certify, identify, or categorize trauma centers) was beyond the reach of the system in that region during the period in study.<sup>10,15</sup>

The cost-effectiveness of trauma-center care was demonstrated in a subsequent study that assessed the value of trauma-center care based on a national outcomes registry representing 14 US states. This investigation showed that the value was most favorable in patients with an injury of higher severity and that these costs were effective in comparison with other life-saving interventions for care of cardiac arrest, severe sepsis, acute respiratory failure, and other general critical care interventions. Moreover, the investigators attributed the cost-effective performance of the individual centers to *regionalization* of trauma care within the 14 states they assessed.<sup>21</sup>

## REGIONALIZATION OF US TRAUMA SYSTEMS AND THE IMPACT ON TRAUMA CARE

Trauma systems are effectively *regionalized* to the extent that the most seriously injured patients (injury severity score >15) in a region are cared for at designated tertiary care trauma centers. This concept is reflective of the notion that an effectively regionalized trauma system is shaped to meet the right patient, right injury, right care, right time paradigm. These centers may be designated by either a regional or state trauma system authority or by the ACS verification process.

In addition, regionalized trauma systems place a limit on the number of tertiary care centers to avoid ineffective redundancy of effort and to sustain trauma care experience within the system based on the concern that lower-volume centers will have insufficient experience to provide optimal trauma care. The ACS COT currently recommends that a level I trauma center admit a minimum of 1200 trauma patients per year and that at least 240 of these patients fall into the seriously injured category, although this threshold has been challenged.<sup>45</sup>

Regionalization of trauma systems may be further impacted by the extent to which the systems are exclusive (ie, all trauma patients go to a limited number of centers for care) or inclusive (ie, all acute care hospitals in a region participate in the care of the injured) based on their capability. Inclusive systems have generally been favored over exclusive systems in that they enable the full capacity of the system to care for the injured while at the same time regulate the most seriously injured to the centers with the greatest capability to care for them. Another potential advantage of the inclusive system is the distribution of regional injury care resources, which would be more favorable in the event of a natural or man-made disaster or act of war or terrorism as discussed by Sofer and Klausner elsewhere in this issue.<sup>21,35,45,46</sup> A potential weakness of the inclusive system is excessive dilution of each center's volume of seriously injured patients thereby creating a suboptimal practice experience for some centers. So, one may assess the effectiveness of an inclusive trauma system by evaluating the distribution of patients within the system based on the severity of the injury bearing in mind that the experience imperative will be served by concentrating the most seriously injured in the higher-volume centers.<sup>45</sup> This methodology has been advanced because it is more effective in providing a functional (high-acuity patients to high-volume centers) as opposed to elemental (high-acuity patients to designated trauma centers) assessment of the system. It also offers an assurance tool in that trauma systems may redesignate centers based on this functional evaluation.<sup>35,45</sup>

In an evaluation of the US trauma system, Diggs and colleagues<sup>45</sup> reported that approximately 7% of US hospitals meet the high threshold volume but that, on

average, based on actual distribution of the seriously injured, the empirically derived threshold that separates a high-volume from low-volume center was 915 patient admissions per year. All categories of seriously injured patients were included in these findings, with the exception of the elderly, most of whom were not admitted to high-volume higher-acuity centers. The study has important implications on 2 major accounts: First, the empiric threshold for a high-volume center was 915, which suggests that the ACS threshold of 1200 may need to be reassessed. Second, elderly patients were not regulated to the high-volume high-acuity centers, indicating that trauma systems exercise a different standard for regionalization of trauma care of the elderly, which is a topic for further study.<sup>45</sup>

### ***Triage Implications in a Regionalized Trauma System***

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Another important indicator of effective regionalization is the efficacy of primary response or early appropriate transfer of the seriously injured to designated trauma centers within a region. In evaluating investigations designed to provide such an assessment, it is important to consider that this may be difficult to measure on a large regional or national level if the investigation was based on the evaluation of a large-volume admission or discharge patient databases. Although a conventional methodology, these investigations may miss the emergency-department-to-emergency-department transfer, which may represent inappropriate initial triage of patients from the scene of the injury.<sup>47</sup>

Although undertriage is an important indicator of ineffective regionalization, secondary overtriage (transfer of patients with minor or no injuries to tertiary care trauma centers) has also been demonstrated as a suboptimal performance consequence in an immature trauma system. This situation leads to overburdened transport and tertiary care resources (not to mention geographic displacement of patients with injuries well within their community's trauma care capabilities).<sup>47</sup> An evolving consequence of patient transfer, certainly amplified by secondary overtriage in immature trauma systems, is the growing problem of repeat imaging because of ineffective regionalization, use, and application of advanced imaging technology. Although the issue appeals to a technical solution, a more effective systems-based approach will include the application of good clinical practice guidelines in image-ordering decision schemes.<sup>48</sup>

In an evaluation of triage and mortality, Utter and colleagues<sup>35</sup> found that the most seriously injured patients were more likely to survive in states with the most inclusive trauma systems (ie, largest proportion of designated trauma centers) but that this did not seem to result from differences in triage patterns. They speculate the reasons that underlie this finding include better early care of severely injured patients by transferring hospitals presumably because of an improved state of readiness and capability to care for the injured that is more distinctive of inclusive trauma systems.<sup>35</sup> In addition, there is evidence that in mature trauma systems, a rigid leveling hierarchy may be less relevant in the regionalization of the severely injured; patient outcomes may be comparable in level I and level II centers.<sup>49</sup> It is important to keep in mind that these results have been demonstrated in retrospect and that in the prospective development of trauma systems such findings are not necessarily generalizable across all centers or systems.<sup>50</sup> They do, however, provide a best-evidence opportunity for shaping the regionalization of a maturing system based on past and potential future performance. Finally, optimal regionalization calls for development of an inclusive regional trauma system that operates based on established and effective primary and secondary triage guidelines and transfer agreements.<sup>45</sup>

## **A FUTURE DIRECTION IN EVALUATING THE IMPACT OF VERIFICATION AND REGIONALIZATION ON TRAUMA CARE: RISK-ADJUSTED OUTCOME MEASURES AND COMPARISONS AS AN INDICATOR OF SYSTEM AS OPPOSED TO CENTER PERFORMANCE**

In recognition of the demonstrated positive impact of the National Surgical Quality Improvement Program on patient outcomes, the ACS has developed a Trauma Quality Improvement Program (TQIP), which is modeled to provide a validated, risk-adjusted, outcomes-based program to evaluate and improve the quality of trauma care. A system of confidential report cards has been implemented in order for participating trauma centers to compare their performance within a peer group according to risk-adjusted mortality benchmarks. This measure represents the first systematic measure and reporting of trauma care quality.<sup>24,51</sup> Future outcome measures, beyond hospital-based mortality, such as rates of preventable morbidity, and quality-of-life indicators, such as measures of functional recovery, may serve to benchmark additional risk-adjusted outcomes. This prospect offers the promise of a robust, validated, and facile assessment and assurance tool to assist with the development and refinement of trauma systems.<sup>24</sup> It has been proposed that the review of trauma center risk-adjusted outcomes may be included in determining trauma center status.<sup>52</sup> Such an assessment would most likely be focused on a review of trauma center performance-improvement applications initiated in response to risk-adjusted trauma center indicators. Although not yet designed, aggregation of validated, risk-adjusted outcome measures within a region may similarly serve as a powerful verification tool in the evaluation of effective regionalization of a trauma system.

The application of performance improvement to trauma system disaster response has been demonstrated to improve regionalization of the severely injured to system trauma centers. Cryer and colleagues<sup>53</sup> report a measureable improvement in the distribution of severely injured patients associated with 2 mass casualty incidents. This report is an excellent example of the application of trauma systems as a public health resource in mass casualty and disaster response. However, it stands in relative isolation as a formally reported *and measured* indicator of the maturation of US or regional trauma systems in mass casualty and disaster response since the 2007 Hoyt and Coimbra *Surgical Clinics of North America* review of US trauma systems.

## **SUMMARY**

Trauma systems allow for improvement of community health in the populations they serve by promoting the effective and efficient use of medical resources. Statewide trauma systems have become more prevalent since the time of initial publication of Hoyt and Coimbra's article,<sup>3</sup> with 90% of US states now having statewide systems.

Trauma systems are regionalized to attempt to meet the right patient, right injury, right care, right time paradigm and to limit tertiary trauma center redundancy. Inclusive systems (ie, those systems whereby all participating hospitals care for injured patients based on their capabilities) have traditionally been favored over the exclusive system, and Utter and colleagues<sup>35</sup> retrospectively demonstrated that this may lead to improved outcome. However, the inclusive system is not without flaws, and the patient volume needed to be designated a high-volume center as well as effective regulation of triage across all patient populations need to be further examined.<sup>45</sup>

With the significant cost of maintaining trauma systems, poor reimbursement, and the evolving global financial crisis, a sustainable source of funding remains a substantial hurdle to be overcome in the ongoing fight to prevent the collapse of US trauma systems. The positive impact that robust trauma systems can have on the outcome

of injured patients has recently been demonstrated in review articles reporting on the experience of the US military's implementation of the JTTS in OEF and OIF.<sup>5-7</sup> Funding for sustainment of the JTS beyond the recent conflict in Iraq and current conflict in Afghanistan has been programmed. The most effective use of those resources requires the JTS and future JTTS are surgeon lead, agile, and current with advancements in trauma care.

Several studies in the civilian literature have demonstrated a mortality benefit associated with care of the injured in a trauma system.<sup>15,29-31</sup> However, these studies assessed mortality benefit, a benefit that matures along with the trauma system and may not indicate actual success in smaller communities given lower patient numbers. Ongoing publication into the measureable and positive impact that trauma systems have on their communities beyond a mortality benefit is essential to ensure continued funding. Work continues on assessment of prehospital and posthospital care and long-term outcomes. In an environment of sustained fiscal austerity with trauma systems competing for limited financial resources, TQIP performance-based outcome measures may more effectively demonstrate trauma system value and garner improved financial support.

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